KEY TO PHYSICS BY EXPERIMENT

SHAW

A KEY TO

SHAW'S PHYSICS BY EXPERIMENT

BY

EDWARD R. SHAW

DEAN OF THE SCHOOL OF PEDAGOGY, UNIVERSITY OF THE CITY OF NEW YORK

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A KEY

TO

SHAW'S PHYSICS BY EXPERIMENT.

Note.—Many of the questions in PHYSICS BY EXPERIMENT are simple, and their answers are self-evident. In this Key answers are given to all questions and experiments where there is any possibility of difficulty or doubt.

CHAPTER I.

Experiment 1, pages 10, 11.

Ten grams over the three-inch mark, balance five grams over the end mark.

When twenty-five grams of weight are placed two inches to the left of the fulcrum, ten grams must be placed five inches to the right, to balance the lever.

The weight remaining the same, twelve and one-half grams must be placed four inches to the right, to balance the lever. And so on.

Experiment 2, page 11.

When the fulcrum is under the three-inch mark, the *Wd* is three inches long, and the *Pd* is nine inches long. Ten grams on the end of the lever will now balance thirty grams weight.

Problems, page 12.

1. P in lbs. $\times$ Pd in feet $\div$ Wd in feet $=$ W in lbs.
   150 $\times$ 5 $\div$ 1 $=$ 750

2. 

FIG. 1.

3. P in lbs. $\times$ Pd in feet $\div$ Wd in feet $=$ W in lbs.

$$150 \times \tfrac{11}{2} \div \tfrac{1}{2} = 1650$$

4. $$150 \times \tfrac{16}{3} \div \tfrac{2}{3} = 1200$$

Questions, page 17.

1. The Wd is part of the Pd in the Second Class of levers.

2. When the thumb-latch is pressed down with the thumb, it represents a lever of the First Class ; when lifted from the other side of the door, it represents a lever of the Second Class.

3. The Pd is part of the Wd in the Third Class of levers.

4. A pair of sugar-tongs belongs to the Third Class of levers ; a lemon-squeezer to the Second Class ; a pair of scissors to the First Class.

5. Illustrations of levers of the First Class : the common pump-handle, a pair of wire-cutters, the key of a piano. Of the Second Class : a door, a desk-lid, a window-catch. Of the Third Class : a pair of sheep-shears, the safety-valve of a boiler, a pair of dividers when properly opened.

6. The weight is never less than the power in levers of the Second Class. The power is always more than the weight in levers of the Third Class.

Problems, page 18.

1. P in lbs. $\times$ Pd in ins. $\div$ Wd in ins. $=$ W in lbs.

$$250 \times 48 \div 8 = 1500$$

It is a simple matter to draw these levers according to scale.

2. W in lbs. $\times$ Wd in ins. $\div$ Pd in ins. $=$ P in lbs.

$$950 \times 9 \div 51 = 167\tfrac{11}{17}$$

3. P in lbs. $\times$ Pd in ins. $\div$ Wd in ins. $=$ W in lbs.

$$225 \times 39 \div 9 = 975$$

4. An oar is a lever of the Second Class.

When the Wd is greater than the Pd, time is gained. When the Pd is greater than the Wd, power is gained.

Experiment 10.

While raising the stone, the spring-balance shows the application of more force than is required to suspend the

stone at rest, because force is required to overcome both the inertia of the stone and the friction of the pulley.

Tests, page 26.

The screws on the ends of wagon and carriage axles are arranged as right-hand and left-hand screws, so that the motion of the wheel may tend to tighten rather than to unscrew the nut.

The turn-buckle is one solid piece, consisting of two nuts, one at each end, joined by two bars. With every turn of the buckle the two rods move towards each other or from each other, according to the direction in which the turn-buckle revolves.

Questions and Problems, pages 27–29.

1. In the treadle of the sewing-machine levers of the First and Third Classes are involved. A lever of the First Class when pressure is made with the heel; a lever of the Third Class when pressure is made with the toe.

2. The product of the power by the power-distance equals the product of the weight by the weight-distance.

3. The three important points of the lever are the fulcrum, the point where the weight is supported, and the point where the power is applied.

4. The wheelbarrow is of the Second Class of levers.

5. Fig. 25 represents a lever of the Second Class, Fig. 26 of the Second Class, Fig. 27 of the First Class.

6. The fore-arm is a lever of the Third Class.

7. W in lbs. $\times$ Wd in ins. $\div$ Pd in ins. $=$ P in lbs.

$$250 \times 21 \div 60 = 87\tfrac{1}{2}$$

8. Considering the beam to be a lever of the Second Class and the support at one end the fulcrum, find the power required at the other end to sustain the weight, 250 lbs. Then regard the other support as the fulcrum and proceed as before. Add to each of these results half the weight of the beam.

$62\frac{1}{2}$ lbs. power + 24 lbs. beam = $86\frac{1}{2}$ lbs. pressure.

$187\frac{1}{2}$ lbs. power + 24 lbs. beam = $211\frac{1}{2}$ lbs. pressure.

9. A lever of the First Class is shown in Fig. 29.

10. The claw-hammer is a lever of the First Class.

11. 2000, W in lbs., $\div$ 8, no. of parts of cord supporting W, $=$ 250, P in lbs.

12. W in lbs. × Wd in ins. ÷ Pd in ins. = P in lbs.
70 × 4 ÷ 13 = $21\frac{7}{13}$

13. P in lbs. × Pd in ins. ÷ Wd in ins. = W in lbs.
250 × 2 × 30 ÷ $\frac{11}{2}$ or $5\frac{1}{2}$ = 2727.27

14. W × height of wagon (Wd) ÷ length of plane (Pd) = P in lbs.
300 × 3 ÷ 7 = $128\frac{4}{7}$

15. Applications of the inclined plane are seen in skids, the treadmill, a winding roadway on a hillside.

16. W in lbs. × Wd in ins. ÷ Pd in ins. = P in lbs.
2000 × 1 ÷ 12 = $166\frac{2}{3}$

17. A force of six tons must be exerted at A.

18. P in lbs. × Pd in ins. ÷ Wd in ins. = W in lbs.
3 × 5 ÷ 2 = $7\frac{1}{2}$

19. W in lbs. × Wd in ft. ÷ P in lbs. = Pd in ft.
800 × 4 ÷ 150 = $21\frac{1}{3}$

20. W in lbs. × Wd in ft. ÷ Pd in ft. = P in lbs.
1000 × $\frac{1}{2}$ ÷ 3 = $166\frac{2}{3}$

21. x = distance of heavier boy from fulcrum, or Pd.
$12 - x$ = distance of lighter boy from fulcrum, or Wd.
$90x = 60(12 - x)$ $\qquad x = 4\frac{4}{5}$ ft.
$150x = 720.$ $\qquad 12 - x = 7\frac{1}{5}$ ft.

22. A door-key is a lever of the First and Second Classes combined.

23–4. If the screw be held vertically, the thread of a right-hand screw slants obliquely downward from right to left ; of a left-hand screw, from left to right.

25. 2240 lbs., W, ÷ 7, no. of parts of cord, = 320 lbs. P.

26. The number of threads to the inch depends upon the diameter of the pencil and the distance that the edge of the paper overlaps.

CHAPTER II.

Experiment 16, page 31.

The height of the mixture is less than the height of the two measures of water first put into the tube.

This is due to the fact that the air in the interstices

between the molecules of water is driven off, and molecules settle into those places.

Page 37.

1–5. See pp. 32, 34, 35.

6. A piece of oak is stronger than a piece of pine, because the cohesion in oak is stronger.

Questions and Problems, page 43.

1. See page 38.

Fig. 2.

2. Both the ball and the slab are elastic and yield slightly with the force of percussion.

3. See page 31.

4. Self-evident.

5. Antimony lacks the property of malleability.

6–7. *General Properties of Matter.*

Magnitude,	possessed	by	sand, smoke, air.
Impenetrability,	"	"	oil, gas, tin.
Divisibility,	"	"	flint, wax, glue.
Indestructibility,	"	"	gossamer, gunpowder, ether.
Porosity,	"	"	porcelain, diamond, aluminum.
Compressibility,	"	"	hydrogen, mercury, iron.
Elasticity,	"	"	mercury, tallow, putty.

Specific Properties of Matter.

Tenacity,	possessed	by	tar, hemp, brass.
Hardness,	"	"	diamond, zinc, quartz.
Ductility,	"	"	glass, brass, silver.
Brittleness,	"	"	resin, pottery, bone.
Malleability,	"	"	most metals.

Experiment 33, page 44.

When the first needle is laid upon the surface of the water, it floats. This is because its weight is not sufficient to overcome the force of cohesion between the molecules and press them aside. When, however, the needle is let fall point downward, its whole weight is brought to bear upon one spot, and the molecules are forced apart.

The needles are held in position because the surface tension between the two needles, tending to draw them together, is just equal to the surface tension on the outside, tending to draw them apart. The alcohol breaks the surface tension between them, and the surface tension from the outside pulls them apart.

Experiment 37, page 48.

The colored brine rises in the test-tube by the capillary attraction in the small spaces between the grains of salt.

Colored water would dissolve the salt instead of rising in the test-tube.

Questions, page 49.

1. See the Summary, page 48.

2. A liquid differs from a gas in the relation between the attractive and repellent forces between the molecules. In a liquid the attractive force is the greater, in a gas the repellent force.

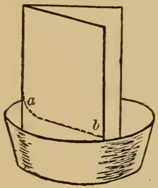

Fig. 3.

3. Gases may be reduced to a liquid condition by pressure and cold.

4. The oil is drawn up the wick by capillary attraction.

5. A capillary tube is any very fine tube.

6. See page 48.

7–8. Due to capillarity.

9. *a b*, Fig. 3, = intersection of surface of water and nearer plate.

10. A drop of water upon the tablecloth spreads rapidly. Kerosene oil is very susceptible to capillary attraction. The flow of sap in trees is due partly to capillary attraction.

CHAPTER III.

Problems, page 53.

1–2. Solution given.

3. At 1,000 miles below the surface the distance has decreased $\frac{1}{4}$. $\frac{3}{4}$ of 500 lbs. = 375 lbs., *Ans.* So 3,000 mi. = $\frac{3}{4}$ of 4,000 mi. $\frac{1}{4}$ of 500 lbs. = 125 lbs., *Ans.*

4. 4,000 mi. + 4,000 mi. = 8,000 mi. from the centre. $8,000 = 2 \times 4,000$. $(\frac{1}{2})^2$, or $\frac{1}{4}$, of 50 lbs. = $12\frac{1}{2}$ lbs., *Ans.*

5. 16,000 mi. + 4,000 mi. = 20,000 mi. from the centre. $20,000 = 5 \times 4,000$. $(\frac{1}{5})^2$, or $\frac{1}{25}$, of 20 lbs. = $\frac{4}{5}$ lbs., *Ans.*

6. 2,000 mi. + 4,000 mi. = 6,000 mi. from the centre. $6,000 = \frac{3}{2} \times 4,000$. $(\frac{2}{3})^2$, or $\frac{4}{9}$, of 1,000 tons, = $444\frac{4}{9}$ tons., *Ans.*

Page 57.

1. A sphere floating in water is in neutral equilibrium.
2. The board is in stable equilibrium.
3. The board is in unstable equilibrium.
4. The larger the base of the inkstand, the lower is the centre of gravity and the more stable is the equilibrium.

5. 

Fig. 4.

Stable.

Fig. 5.

Unstable.

6. 

Fig. 6.

Stable.

Fig. 7.

Unstable.

7. 

Fig. 8.

Stable.

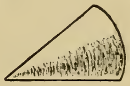

Fig. 9.

Neutral.

8. The line of direction of the Tower of Pisa falls within the base.
9. The weight of the arm, when thrown out, moves the centre of gravity farther from the pail and causes the line of direction to fall farther within the base.
10. A cylinder can be placed in stable and in neutral equilibrium.

11. The load of stone is the more stable, the centre of gravity being nearer the base.

12. When standing in the bottom of the boat, the centre of gravity is brought nearer the base.

13. A pyramid is a stable structure, because its broadest section is at the base and its centre of gravity is near the base.

Page 60.

1. The motion of a body is accelerated when its velocity increases.

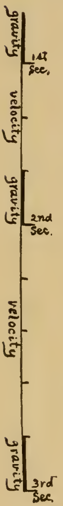

Fig. 10.

2. The motion of a body is uniformly accelerated when its velocity increases by a constant quantity in each successive interval of time.

3. Examples of retarded motion are seen in a railway train coming to a stop, a rifle-ball when it is nearly spent, and a marble rolled across the floor.

4. The motion of a body is uniformly retarded when its velocity decreases by a constant quantity in each successive interval of time.

5. The motion of the ball is uniformly retarded.

8. As much work was done in the one instance as in the other, viz., 16.000 ft. lbs.

9. $12\frac{1}{2}$, W in lbs., $\times$ 42, velocity in feet, = 525, momentum in lbs.

Page 61.

1. $2 \times 32 = 64$, distance in feet that the body would be carried by velocity alone.

2. See Fig. 10.

3. 7^2 (no. of seconds squared) $\times$ 16 ft. = 784 ft., *Ans.*
$7 \times 2 - 1 = 13$. 13×16 ft. = 208 ft., *Ans.*

4. 448, velocity in ft., $\div$ 32 = 14, no. of seconds.

5. Starting with a velocity of 256 ft. the arrow will rise to just that height from which it must fall to acquire a velocity of 256 ft. $256 \div 32 = 8$, no. of seconds of ascent. $8^2 \times 16$ ft. = 1024 ft., height to which it will rise.

6. In the whole time, 5 secs., the first stone has fallen 400 ft. In 2 secs., the second stone falls 64 ft. 400 ft. — 64 ft. = 336 ft. apart, *Ans.*

Page 66.

4.

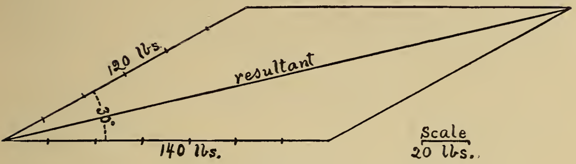

FIG. 11.

5.

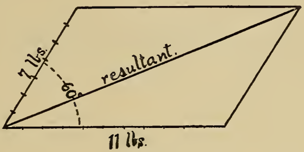

FIG. 12.

6.

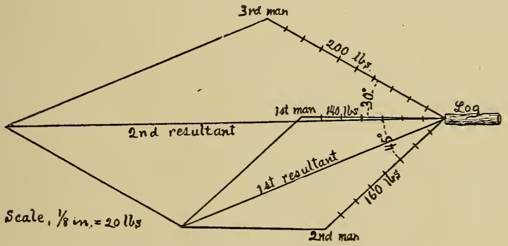

FIG. 13.

Experiment 50.

The pendulum moves from A to B by the force of gravitation. It does not stop at B, because of its inertia and the momentum it has acquired, which is sufficient to overcome the gravitation until the pendulum reaches C. The motion

from A to B is uniformly accelerated ; from B to C, uniformly retarded. The pendulum finally comes to rest, because the force imparted to it is at length expended in overcoming the resistance of the air.

Experiment 51.

The pendulums make the same number of vibrations in a minute. A change in the weight at the end does not affect the time of vibration.

Questions and Problems, page 70.

1. See Experiment 50.
2. See page 67.
3. The length is 39.1 inches.
4. A pendulum at New York, to vibrate once in two seconds, must be four times 39.1 inches, or 156.4 inches.
5. If a clock loses time, its pendulum is too long.
6. The times of vibration are as $\sqrt{16}$ to $\sqrt{36}$, or as 4 to 6, or as 2 to 3, respectively.

Page 73.

At A and C the pendulum has potential energy, at B it has kinetic energy.

Page 74.

When the stone has passed over one-third of the entire distance of its descent, one-third of its energy is kinetic and two-thirds are potential.

Questions and Problems, page 77.

1. One's weight would be doubled.
2. They exert one-fourth as much attraction toward each other. $\frac{1}{2^2} = \frac{1}{4}$.
3. 4,000 mi. + 4,000 mi., distance from centre to surface, = 8,000 mi., distance of the body from centre of earth.

8,000 = 2 × 4,000. $(\frac{1}{2})^2$, or $\frac{1}{4}$, of 4,000 lbs. = 1,000 lbs., *Ans.*

4. The distances moved over are inversely proportional to the masses. 150 lbs. : 450 lbs. : : 1 : 3, or $\frac{1}{4}$: $\frac{3}{4}$.
$\frac{1}{4}$ of 10 mi. = $2\frac{1}{2}$ mi., distance larger body would move.
$\frac{3}{4}$ of 10 mi. = $7\frac{1}{2}$ mi., distance smaller body would move.

5. The velocity per second is 150 ft. ÷ 3 = 50 ft.

6. The round body is always in neutral equilibrium ; the square body is sometimes in stable equilibrium.

7. The ball is in unstable equilibrium because the line of direction falls outside of the base. See Fig. 14.

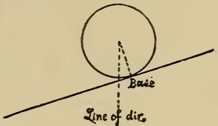

FIG. 14.

8. $\sqrt{16} : \sqrt{36} :: 4 : 6$.

9. $4^2 = 16$. 16×16 ft. = 256 ft. high.

10. $12 \times 800 = 9{,}600$ lbs., momentum of first ball.
$15 \times 500 = 7{,}500$ lbs., momentum of second ball.

11. The steamboat continues to move because of its inertia and momentum.

12. $9^2 \times 16$ ft. = 1,296 ft., *Ans.*

13. Two plumb lines are not exactly parallel, because, if prolonged, they would meet at the centre of the earth.

14. $3 \times 2 \times 16$ ft. = 96 ft. velocity. 240 lbs. momentum.

15. The earth must be removed $\sqrt{9} \times 93{,}000{,}000$ miles, or 279,000,000 miles from the sun.

16. The centre of gravity of the ring is in space in the centre of the curve.

17. The elder pith is very light, the centre of gravity is within the lead, and the witch, when laid on its side, is in unstable equilibrium.

18. See Experiment 50 and explanation. A pendulum without friction and in a perfect vacuum would never cease to vibrate.

19. $9 \times 2 - 1 = 17$. 17×16 ft. = 272 ft. in the ninth second. $9^2 \times 16$ ft. = 1,296 ft. in 9 seconds.

20. 1,500 mi. = $\frac{3}{8}$ of 4,000 mi. The body is $\frac{5}{8}$ as far from the centre as it would be at the surface. $\frac{5}{8}$ of 500 lbs. = 312.5 lbs., *Ans.*

21. $352 \div 32 = 11$, no. of seconds of ascent. $11^2 \times 16$ ft. = 1,936 ft. high. Before the ball reaches the ground, 22 seconds will elapse.

22–23. See the Summary, page 78.

24. The bird could not move, because it would have no matter upon which to exert the pressure of its wings, in order to overcome the inertia of its body.

25. $150 \times 140 = 21{,}000$ ft. lbs. of work.

26. $\frac{\frac{1}{2} W V^2}{32} = K. E.$ $\qquad \frac{\frac{1}{2} (82) \times \overline{26}^2}{32} = 866\frac{1}{8}$ ft. lbs.

27. A velocity of a mile a minute is 88 feet a second.

$$K. E. = \frac{\frac{1}{2} (160{,}000) \times \overline{88}^2}{32} = 19{,}360{,}000 \text{ ft. lbs.}$$

28. $\frac{\frac{1}{2} (2{,}000{,}000) \times \overline{720}^2}{32} = 16{,}200{,}000{,}000$ ft. lbs., $K E$ of 1st boat.

$\frac{\frac{1}{2} (2{,}000{,}000) \times \overline{815}^2}{32} = 20{,}757{,}031{,}250$ ft. lbs., $K E$ of 2d boat.

Total energy expended $= 36{,}957{,}031{,}250$ ft. lbs.

29. The earth should rotate more than seventeen times as fast as now. See foot note, page 53.

CHAPTER IV.

Experiment 61, page 84.

If we press down on the surface of the water in tube B with a force of twelve pounds, the water in each of the tubes C and D will exert an upward pressure of twelve pounds, because water transmits pressure equally in all directions. But this is true only on condition that the tubes C and D are of exactly the same cross section as tube B. For when liquids are subjected to pressure, the amount of pressure received upon any part of the surface restraining the liquid is in direct proportion to the area of that surface. So, as the surface of the water in E has twice the area of the surface of the water in B, it will exert an upward pressure of ten pounds, when there is a downward pressure of five pounds on the surface of B. The water in E will rise only half the distance that the stopper B is pushed down.

Questions, page 88.

1. 3 ft. × 4 ft. × $2\frac{1}{2}$ ft. = 30 cu. ft., contents of tank. 30 × $62\frac{1}{2}$ lbs., weight of one cu. ft. of water, = 1875 lbs.

2. 78 in. = $6\frac{1}{2}$ ft. 5 sq. ft. × $6\frac{1}{2}$ ft. = $32\frac{1}{2}$ cu. ft., contents of tank. $32\frac{1}{2}$ × $62\frac{1}{2}$ lbs. = $2031\frac{1}{4}$ lbs.

3. The pressure upon the base of a cubical vessel is at once the weight of the liquid. Since, in finding the pressure upon the side of the vessel, only half the depth of the liquid is used, the pressure upon the side equals one-half the weight of the liquid.

4, No. of sides, × $\frac{1}{2}$ weight of liquid = 2 times the weight. Hence, with the pressure upon the base, the total pressure upon a cubical tank is three times the weight of the liquid.

4. 30 ft. × 26 ft. = 780 sq. ft., surface pressed upon. 780 sq. ft. × 13 ft., depth to middle point of surface pressed upon, = 10,140 cu. ft. 10,140 × $62\frac{1}{2}$ lbs. = 633,750 lbs., *Ans.*

Experiment 66, page 92.

The pressure upon the rubber of the Cartesian diver is transmitted to the water. The water, being practically incompressible, is displaced, and so forced into the smaller bottle, compressing the air there. The smaller bottle, being made heavier by the added water, sinks.

Experiment 67, page 93.

The amount of pressure at Q and at P is exactly the same; and if Q were closed, the pressure there exerted would counterbalance the pressure at P. But as there is nothing at Q to receive this pressure, the water flows without opposition; and in seeking a similar outlet at P it exerts its force against the side of the tube and moves the mill.

Questions and Problems, pages 94, 95.

1. Liquids at rest exert pressure in all directions. At the upper surface, however, they exert no pressure upward.

2. The pressure of a liquid upon the bottom of a vessel depends (1) upon the area of the surface pressed upon, (2) upon the depth of the liquid, (3) upon its specific gravity.

3. A piece of floating wood displaces a quantity of water equal in weight to itself.

4. See the Summary, page 94.

5. A cubic foot of distilled water weighs $62\frac{1}{2}$ lbs.

6. The water rushes up the chimney for the same reason that water in communicating pipes will rise as high as its source.

8. While the stone is being lifted through the water, the weight of a quantity of water equal in volume to the stone is buoying it up.

9. The weight of the water displaced by the human body, and hence the upward pressure, is a little greater than the weight of the human body.

10. See page 84.

11. An iron ship floats, because the hull of the ship being hollow and filled with air, the quantity of water equal in volume to the hull weighs more than the ship.

12. 1 ft., depth of tank, + 3 ft., length of pipe, = 4 ft., or 48 ins., total height of column of water.
48×2, number of sq. ins. in base of column, = 96 cu. in.
$\frac{96}{1728} \times 62\frac{1}{2}$ lbs. = $3\frac{17}{36}$ lbs., *Ans.*

13. An equal volume of water weighs 15 lbs. − 10 lbs., or 5 lbs. The specific gravity is $\frac{15}{5}$, or 3.

14. Iron floats in melted copper.

15. The following solids will float on mercury: lead, silver, copper, brass, iron, tin, zinc, marble, etc.

16. A person floats more easily in salt water, because of its greater specific gravity.

17. Spec. grav. of the ore = $\frac{40}{30}$, or $1\frac{1}{3}$.

18. 40 oz. × .88 = 35.2 oz., weight of a quart of petroleum.
$38\frac{1}{2}$ lbs., or 616 oz. ÷ 35.2 = 17.5, no. of quarts, or 4.375 gals.

19. The specific gravity of sea water being greater than that of fresh water, the vessel displaces more water in the river, and therefore sinks deeper.

20. 25 ft. × 10 ft. = 250 sq. ft., surface pressed upon.
260 sq. ft. × 5 ft., depth to middle point of surface, = 1250 cu. ft.
1250 × $62\frac{1}{2}$ lbs. = 78,125 lbs., *Ans.*

CHAPTER V.

Page 99.

In order to perform Experiment 71 with water, the tube should be 13.6×30 ins., or 34 ft., long.

If the mercury stands at 28 ins., in order to perform this experiment with water the tube should be 13.6×28 ins., or 31.733 ft., long.

Experiment 72.

When the air is withdrawn from the tube, the pressure of the atmosphere is removed from the surface of the water within the tube, and the atmospheric pressure upon the surface of the water in the tumbler forces it up the tube.

If all the air could be exhausted from a tube 36 ft. long, the water would rise 13.6 (see page 99) times 30 ins., or 408 ins., or 34 ft.

Experiment 74, page 102.

As the water rises in the air-chamber of the force-pump, it compresses the air. This, in expanding, forces the water out, and continues so to do while the piston is being raised for another stroke, when the air is again compressed. Thus a continuous stream of water is produced.

The Siphon, page 105.

The greater the difference between the levels of the liquid in the two vessels, the greater is the difference between the weights of the columns $A\ B$ and $C\ D$, and hence the greater is the difference between the net upward pressures at A and D, and the more rapid will be the flow of water.

The size of the tube makes only a slight difference in the velocity with which the liquid flows, due wholly to the difference in the amount of friction offered by the sides of the tube. In a larger tube the flow will be a little more rapid. Aside from this it is evident that a large

tube will empty a vessel sooner than a small one because of its greater capacity.

The height of the shorter arm is limited to 34 ft., because water cannot be raised by the atmospheric pressure above that height. When the liquid is at the same level in the two vessels, the flow stops, because the columns *A B* and *C D* then exert the same downward pressure, and therefore the net upward pressure at *A* is no greater than at *D*.

Experiment 78, page 108.

The difference between the readings of the shorter tube and the longer tube should be the same as the reading of the barometer on the day of the experiment. When the air in the shorter tube is compressed to half its original volume, it is under a pressure of two atmospheres ; when it occupies twice the original space, it is under half an atmosphere pressure.

Questions and Problems, pages 110, 111.

1. The elder pop-gun works upon the principle of the compressibility and elasticity of the air.

2. See Experiment 70.

3. The siphon with the long arm of 3 ft. will empty the vessel the quicker ; for, as a column of water 3 ft. long is heavier than a column 18 ins. in length, the ultimate difference between the upward pressure in the longer and shorter arms of the longer siphon is greater than this difference of pressure in the shorter siphon.

4. Evident from the elasticity of air and carbon dioxide.

5. A valve is a tightly closing lid, usually made so as to open in only one direction.

6. 30 ins. : 27 ins. :: 14.7 lbs. : 13.23 lbs., *Ans.*

7. The water can be pumped out of any well where the perpendicular distance from the surface of the water to the piston when raised is somewhat less than 34 ft.

8. 7 × 900 ft. (see page 100) = 6,300 ft., height of mountain. 30 ins. : 22 ins. :: 14.7 lbs. : 10.78 lbs. pressure.

9. The paper seals the glass, preventing the entrance of the air at any one point, and allowing the atmospheric pressure to sustain the water.

10. A vacuum is space devoid of all matter.

11. Water may be raised out of a well 40 ft. deep by using a pump with a plunger of such a length that, when it is raised, the piston-head shall be somewhat less than 34 ft. above the surface of the water in the well.

12. Left for the student.

13. Theoretically the air could sustain a column of water 13.6 (see page 99) $\times$ 28 ins., or 31.73 ft., in height ; but because a perfect vacuum cannot be made by an ordinary pump, and because the construction of the pump demands that the water shall rise a few inches above the lower valve, the valve must be placed somewhat less than 31.73 ft. above the surface of the water in the well.

14. Air not only exerts pressure downward, but it transmits that pressure in all directions.

15. The pressure exerted upon the air by the closing door is transmitted through the adjoining room to the remote door. Or, a different case, the closing door removes the atmospheric pressure from the inner side of the remote door, and the atmospheric pressure on its outer side closes it.

17. The gas will occupy half its original volume, or half a cubic foot.

CHAPTER VI.

Questions and Problems, page 119.

From Fig. 103 it is evident that there are $\frac{180}{100}$ or $\frac{9}{5}$ as many degrees between two temperatures on the Fahrenheit scale as on the Centigrade, and $\frac{5}{9}$ as many on the Centigrade scale as on the Fahrenheit. Hence, to reduce from Centigrade to Fahrenheit, multiply by $\frac{9}{5}$ and add 32°, because 0° C. = 32° Fahr. And to reduce from Fahrenheit to Centigrade, subtract 32° and multiply by $\frac{5}{9}$.

1. $\frac{9}{5}$ of 72° = 129.6° in Fahrenheit degrees.
2. 60° − 32° = 28°. $\frac{5}{9}$ of 28° = $15\frac{5}{9}$° C.
3. *Answers :* 10° C., $11\frac{1}{9}$° C., − 40° C., $93\frac{1}{3}$° C., $7\frac{7}{9}$° C.
4. $\frac{9}{5}$ of 80° = 144°. 144° + 32° = 176° Fahr.

Answers : 59° Fahr., 41° Fahr., − $\frac{2}{5}$° Fahr.

5. *Answers :* $48\frac{8}{9}$° C., 176° Fahr., $17\frac{7}{9}$° C., − $\frac{2}{5}$° Fahr., $65\frac{5}{9}$° C., − $35\frac{5}{9}$° C., $37\frac{7}{9}$° C.

Experiment 92.

The gauze conducts away the heat of the flame so rapidly that the gas on the side of the gauze opposite the flame cannot become heated sufficiently to ignite.

Page 129.

When water boils, all the air is expelled from the vessel containing the water, and its place filled by steam. There being, therefore, nothing to impede the motion of the water as it is thrown about, it strikes directly against itself and against the glass without the usual intervening cushion of air, and so produces a clicking sound. Whatever cushion of steam there may be is instantly dissolved.

Experiment 98.

A rise in temperature, an increase in the extent of surface, and removal of pressure of the atmosphere, all increase the evaporation.

Experiment 101.

Should it be found difficult to obtain satisfactory results with Experiment 101, the following may be substituted :

Put half a pound of iron filings into a beaker and suspend the beaker for some minutes in a vessel of water, which is to be kept boiling, stirring the filings meanwhile with the bulb of a thermometer. Weigh out half a pound of water of ordinary temperature in another beaker, and set this on a number of thicknesses of cloth or paper, to prevent contact with the table. When the temperature of the filings has ceased to change, note it ; and then, after the thermometer has been allowed to cool, note the temperature of the water in the other beaker. Now remove the beaker of filings from the vessel of boiling water and pour them into the beaker of water, stirring constantly with the thermometer. When the temperature of the mixture has

ceased to change, note it. It will be found that the water has risen in temperature and the iron has fallen, to the temperature of the mixture. The one has evidently gained as much heat as the other has lost, but the changes in temperature have been different. By dividing the number of degrees of change in the water by the number of degrees of change in the iron, the specific heat of the iron may be found. Error may be prevented by having the temperature of the thermometer that expected in the mixture before stirring the mixture.

Experiment 102, page 133.

The ether, in evaporating, takes the heat from that with which it is in contact; first from the cotton; the cotton takes it from the glass; the glass takes it from the mercury. This contracts, and a lower reading is seen on the thermometer.

Experiment 103, page 133,

We are unable to form ice upon the sheet of copper as upon the wood; for as soon as any part of the copper is cooled, heat is immediately conducted thither through the surrounding metal.

Questions and Problems, pages 142–145.

1. See the Summary, page 141.
2. Cold is the absence of heat.
3. Ice has a low degree of heat.

4, 5, 6. See the Summary, page 141.

7. A thermometer is an instrument for measuring temperature; a barometer, for measuring atmospheric pressure.
8. See explanation to the problems on page 19 of the Key.

$-40°$ C. $\times \frac{9}{5} + 32° = -40°$ Fahr. $\therefore -40°$ Fahr. $= -40°$ C.

9. $\frac{5}{9}(-36° - 32°) = -37\frac{7}{9}°$ C.
10. *Answer:* $-6\frac{2}{3}°$ C.
11. *Answer:* 68° Fahr.

12. The bore of a thermometer should be uniform throughout; for as the degrees are always of equal length, it would otherwise not indicate temperature correctly.

13. Heat cannot be passed from a colder to a hotter body.

14. Heat usually increases the size of an object.

15. Ice, cast iron, bismuth, antimony are exceptions to the foregoing rule.

16. The human body takes note of only comparative temperatures.

17. Evident from the answer of No. 16.

18. For measuring the highest temperatures an instrument called a pyrometer is used. Formerly it was simply a thermometer made of hard metal, but the apparatus now employed is based upon the phenomena of thermo-electricity.

19. For medium and low temperatures a mercurial thermometer will answer.

20. For extremely low temperatures alcohol is best. It has recently been solidified at $-130.5°$ C.

21. When the axles of coach-wheels are not greased, they expand with the heat caused by the friction to such a degree as to stop the wheel.

22. Because the rails contract in winter and widen the spaces.

23. Wagon-tires are put on wheels when hot in order that, as the tires contract with cooling, they may bind the parts of the wheel tightly together.

24. The fixed points of a mercurial thermometer are the zero point and the temperature at which distilled water boils.

25. Glass is a poor conductor of heat. When suddenly heated, therefore, it expands irregularly. This tends to bend the glass, and, being brittle, it breaks.

26. See Experiment 104.

27. See Experiment 91.

28, 29. The warm carbon dioxide given off from the lungs is lighter than the surrounding air, therefore the bubble ascends. But this gas when cold is heavier than air ; hence the bubble soon descends again.

30. From the preceding answer we should conclude that the bad air of a room is near the ceiling. For ventilation, therefore, two openings should be provided ; one near the ceiling, as an exit for the bad air, the other lower down, to admit the pure air.

31. There being a greater difference in density between the outside

air and that immediately above the fire on a cold day than there is on a warm day, a better draught is caused.

32, 33. Left for the student.

34. When a fire is first lighted, there is often not sufficient heat to cause a draught, the air in the chimney does not rise, and the smoke comes into the room.

35. When the hand is laid on a piece of cold iron, the heat imparted to the metal is conducted immediately away. The hand thus becomes cooled, and we feel the sensation. Wood, however, is a poor conductor, and remains warm beneath the hand.

36. Evident from the preceding answer.

37. Flannel is a poor conductor of heat.

38. The carpet is not so good a conductor as the marble, and hence feels warmer.

39. If both were warmer than the body, the marble would seem to have the higher temperature.

40. Linen and cotton sheets are better conductors than woollen blankets.

41. The glass of the thermometer is not an absolute non-conductor.

42. Glass has the property of allowing luminous rays of radiant heat to pass through it, but not dark, or obscure, rays. Hence the sun's rays readily enter the hot-bed, but the obscure rays of heat reflected and radiated from the earth cannot pass beyond the glass, and expend themselves upon the air beneath. All around the hot-bed, however, the obscure rays from the earth reach to a greater elevation, and their heat, being communicated to a greater depth of atmosphere, does not raise its temperature so high.

43. Double windows prevent heat from escaping, because the air confined between the two glasses acts as a non-conductor. Furthermore, when there is only one thickness of glass, as soon as heat from the room has been communicated through the glass to the air outside, this warm air moves away, and thus there is always cold air in contact with the glass, which cools the room. By a double window the air warmed from the room is imprisoned, and the cold air cannot come in contact with the glass next to the room.

44. The covering of snow prevents radiation from the earth.

45. The large quantity of air in the snow renders snow a poor conductor.

46. Heat increases evaporation.

47. Bright pans do not absorb the heat of the oven as readily as dark ones.

48. The rapidity of evaporation is affected by temperature, extent of surface, atmospheric pressure, and the amount of moisture in the atmosphere.

49. Water will boil at a lower temperature on the top of a mountain than at the sea level, because the atmospheric pressure is less.

50. The boiling-point of a liquid is affected by diminished pressure, increased pressure, and the amount of foreign matter present.

51. See the Summary, page 142.

52. See answer for page 129, on page 20 of the Key.

53. The steam rising through the water and escaping at the surface causes boiling water to bubble.

54. Distillation depends upon the principle that by means of heat a liquid or solid may be expanded into a gas, and by means of cold this gas may be again condensed into the liquid or solid state, as the case may be.

55. Latent heat can be changed into sensible heat.

56. The current of air from the fan evaporates the insensible perspiration.

57. The cold pitcher condenses the moisture in the atmosphere of the room.

58. Salt causes ice to melt because of the affinity of the salt for water. In melting, the ice takes the sensible heat from objects around it. to be turned into latent heat, and thus renders surrounding bodies cold.

59. The steam is condensed on the cold tumbler.

60. The watery vapor in the breath is condensed.

61. By the maximum density of water we understand that condition when the molecules are closest together, or when a given amount occupies the least possible space. Water reaches its maximum density at 39.2° Fahr.

62. As water expands in freezing, the specific gravity of ice is less than that of water at ordinary temperature.

63. As water freezes at 32° and reaches its maximum density at 39.2°, it must occupy more space when frozen.

64. Heat may be diffused by conduction, by convection, by radiation.

65. The earth's surface is heated by radiation from the sun.

66. The atmosphere is heated by radiation from the sun and from the earth, and by convection as it comes in contact with the warm earth.

67. A good absorbent is not a good reflector.

68. There is no reason why a good conductor should or should not be a good radiator. The conditions that make the one are entirely different from those that make the other.

69. After the water reaches 212° all heat is expended in changing the water to steam.

70. Boiling is noisy, evaporation is quiet; boiling takes place within the body of the liquid, evaporation takes place at the surface.

71. The water on the floor evaporates. In so doing it changes the sensible heat of the atmosphere to latent heat within itself, and the atmosphere becomes cooled.

72. The water was caused to circulate by the cold. The circulation stopped when the water reached the temperature 39.2° Fahr.

CHAPTER VII.

Experiment 131, page 162.

Because of the extreme lightness of the lycopodium, the currents of air produced by the vibrations draw it away from the nodes.

Questions and Problems, pages 169–171.

1. Vibration is motion back and forth. Amplitude of vibration is the distance a body moves from the farthest point on one side of its position of rest to the farthest point on the other side.

2. See the Summary, page 167.

3. The particles in a water-wave move up and down, or at right-angles to the direction taken by the wave. In a sound-wave the particles of air move back and forth, or along lines parallel to the direction taken by their respective parts of the wave.

4. A wave length includes one complete crest and one complete trough, or it includes one complete condensation and one complete rarefaction.

5. See the Summary, page 168.

6. 27 ft. $\div$ 16 $= 1\frac{11}{16}$ ft., average length of waves.

7. 1,120 ft. $\div$ 560 $=$ 2 ft., wave length.

8. 1,120 ft., velocity of sound, $\times$ 4, no. of seconds, $=$ 4,480 ft. distant.

9. See Experiment 129.

10. 1,120 ft. $\div$ 512 = $2\frac{3}{16}$ ft., length of sound wave.

11. A sound wave is spherical in form.

12. Sound travels less rapidly in air than in liquids and solids.

13. The larger string will produce a tone of lower pitch.

14. The longer string will produce the lower tone.

15. The string subjected to the more tension will produce a tone of higher pitch than the other.

16. See page 151.

17. This question cannot be answered by saying that, as water is a good conductor of sound, a mixture of water and air will convey sound with greater readiness than air alone. For the presence of watery vapor in the atmosphere tends to diminish rather than to increase its conductivity. According to Tyndall, the explanation is that on some days, apparently clear, there are invisible striæ of aqueous vapor in the atmosphere, which intercept the passage of the sound-waves. If there be no such striæ, however, sounds will travel to much greater distances even in a thick haze. Further, in foggy weather, when the air is perfectly still and the water calm, the sound-waves travel more readily than when they are broken by rough weather.

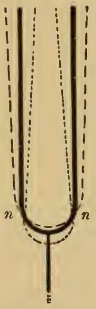

Fig. 15.

18. Left for the student.

19, 20. See the Summary, page 168.

21. An echo is sound heard after reflection.

22. $\frac{1}{2}$ of 20 secs. = 10 secs., time required for the sound to travel one way, from the rocks to the observer. 1,090 ft., velocity of sound, $\times$ 10 = 10,900 ft., or 2.06 miles, distance of rocks.

Or, 1,120 ft., velocity of sound, $\times$ 10 = 11,200 ft., or 2.12 miles.

23. The intensity of sound heard by the first observer is to the intensity of sound heard by the second observer as 2^2 distance of the second observer, is to $(\frac{1}{4})^2$ distance of the first observer, or as 4 is to $\frac{1}{16}$, or, reducing, as 64 is to 1.

24. Left for the student.

25. "Musical sound is that which produces a continuous sensation, and the musical value of which can be estimated; while noise is either a sound of too short a duration to be determined, or else is a confused mixture of many discordant sounds."—*Ganot.*

26. 126 $\times$ 2 = 252 vibrations, *Ans.*

27. See page 160.

28. The middle C has 264 vibrations per second.
1,120 ft. $\div$ 264 = $4\frac{8}{33}$ ft., wave length.

29, 30. See the Summary, page 168, and Figs. 131, 138.

31–33. See the Summary, pages 168–9.

34. A tuning-fork has a node on each side by the handle; and unless it be a perfect one, it will show nodes in other places. They may be located by a bead suspended by a thread. (See Fig. 15.)

35. The harder one blows, the greater is the speed with which the disk revolves, and therefore the greater is the number of vibrations per second.

CHAPTER VIII.

Experiment 140, page 174.

There are two light shadows, because the shadow cast from each candle is in part lighted by the other candle. But where these two shadows overlap, light is received from neither candle, and a dark shadow is the result.

Constructions, page 184.

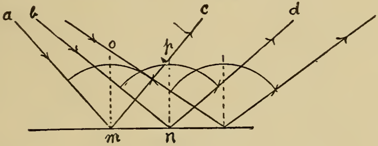

FIG. 16.

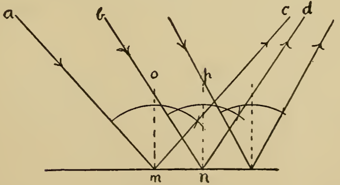

FIG. 17.

a m o, angle of incidence, = *o m c*, angle of reflection.

b n p, angle of incidence, = *p n d*, angle of reflection, and so on.

Experiment 153.

A convex mirror forms a virtual image.

Questions, pages 211, 212.

1. Luminous bodies are bodies that emit light.

2. See page 172.

3. A shadow is a portion of space from which light is excluded by an intervening body.

4. The umbra is formed by the exclusion of all the light, the penumbra by the exclusion of only part of the light.

5. A part of the luminous body can be seen from the penumbra.

6. The intensity of light varies inversely as the square of the distance from the source of light.

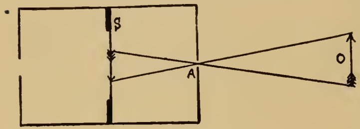

FIG. 18.

7. The images formed by means of small apertures are inverted. For, as the rays of light from the object O, in order to reach the screen S, must pass through the aperture A, they must there cross, rendering the image inverted.

8. M = mirror.
$O P$ = perpendicular.
$A O$ = incident ray.
$O B$ = reflected ray.
$A O P$ = angle of incidence.
$B O P$ = angle of reflection.

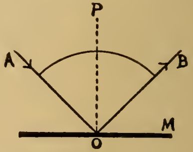

FIG. 19.

9. A real image can be thrown upon a screen, a virtual image cannot.

10. See Fig. 154.

11. One image is seen by reflection from the back of the mirror, and a second is seen by reflection from the front of the glass. Other images, sometimes above, sometimes below these, are formed by rays of light which, coming from the object and reflected by the back of the mirror, undergo total reflection at the front surface of the glass, and afterwards a second or even a third and fourth reflection from the back of the mirror, before reaching the eye. The image formed by the back of the mirror is the brightest, because of the superior reflecting power of mercury.

12. In diffusion of light the rays are scattered; in reflection they bear a definite relation; by absorption they disappear within the absorbing substance.

13. The image formed by a plane mirror is of the size of the object, and just as far behind the mirror as the object is in front of it.

14. If a ray of sunlight strikes the side of a prism at a sufficiently small angle, it will be reflected instead of entering the prism.

15. $360° \div 30° = 12$. $12 - 1 = 11$, no. of images.
$360° \div 120° = 3$. $3 - 1 = 2$, no. of images.

16. The image formed by a convex mirror is smaller than the object.

17. When the object is near a concave mirror [*i. e.*, not as far away as twice the focal length of the mirror] the image is larger than the object. When the object is far removed from a concave mirror [*i. e.*, beyond the centre of curvature, or beyond twice the focal length] the image is smaller.

18. The laws of refraction, page 188, are obeyed.

19. See page 191.

20. Hold the lens in the direct rays of the sun and let them come to a focus upon a piece of white paper. Move the paper until the spot of light upon it is as small as can be obtained. The distance from the paper to the lens will be the focal length of the lens.

21. The band of seven colors formed by the decomposition of rays of sunlight is known as the solar spectrum.

22. Violet, ultramarine blue, etc., as on page 195, only in the reverse order. Red is the least refracted.

23. See the Summary, page 210.

24. See pages 202, 203.

25. Violet, etc , as on page 195. Red, etc., in the reverse order.

26. Two refractions and two reflections are required to produce the secondary bow; two refractions and one reflection, to produce the primary bow.

27.

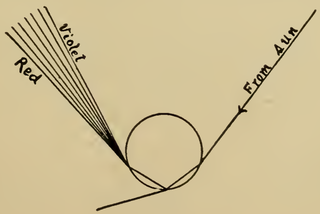

FIG. 20.

28. In near-sightedness the globe of the eye is too long; in far-sightedness it is too short. For the former concave glasses are required; because, as the crystalline lens brings the rays to a focus before they reach the retina, it is too powerful, and the opposite kind of a lens must counteract its effect. In the latter, as the rays are not brought to a focus soon enough, the lens of the eye is too weak, and must be reënforced by a convex lens.

CHAPTER IX.

Experiment 179, page 220.

When like poles are together, one reënforces the other, and the key is sustained. When unlike poles are together, the key falls.

Questions, pages 225, 226.

1. Lines of force are imaginary lines radiating from the poles of a magnet, along which its energy is exerted.
2. The magnetic field is the space through which the influence of a magnet extends.
3. By the polarity of a magnet is meant its property of exerting opposite tendencies at its poles.
4. See page 217.
5. See page 213.
6. The neutral line of a magnet is a line extending around the magnet midway between the poles, which exhibits neither powers of attraction nor repulsion.
7. As the lines of force extend more readily through iron than through the air, the armature keeps them in closer proximity to the magnet, and so preserves the strength of the magnet.
8. Every molecule of a magnet possesses polarity. When, therefore, a magnet is broken, each face of fracture must exhibit that property.
9. See page 222.
10. See page 223.
11. The magnetism may be destroyed by heating the magnet.

12.

FIG. 21.

13.

FIG. 22.

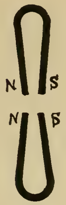

FIG. 23.

14. The magnetic needle points approximately northward toward the magnetic pole.

15. The magnetic needle does not always point in one direction, as the line of no variation is slowly moving, and the declination is, therefore, not constant. There are, besides, other slight variations of the needle, known as daily and yearly variations.

16, 17. See page 219 and note.

Experiment 189.

Negative electricity is developed on the sealing-wax, positive on the flannel cap.

Experiment 192.

The sealing-wax is charged with negative electricity. On the side of the tin next the sealing-wax there is positive electricity, on the opposite side there is negative.

LAW OF INDUCTION.—When an electrified body is brought near an unelectrified conductor there is induced on the nearer side of that conductor electricity of a kind opposite to that possessed by the electrified body, and on the farther side of the conductor electricity is induced of the same kind as that possessed by the electrified body.

Experiment 194.

When you touch the upper side of c with the finger, negative electricity passes to the earth; and when c is lifted, it is charged with positive electricity.

Experiment 196.

See answer to question 9 of page 237.

Questions, pages 236, 237.

1. Bodies charged with unlike kinds of electricity attract each other ; bodies charged with like kinds repel each other.

2. See Experiment 189.

3. Substances that offer a free passage to electricity are called conductors ; those substances which do not allow electricity to flow over or through them are called non-conductors, or insulators.

4. See Experiment 188.

5. See Experiment 193 and Fig. 206.

6. All unelectrified bodies are supposed to be covered with both positive and negative electricity in equal amount, so that the one neutralizes the other. When an electrified body is brought near, it decomposes this neutral electricity, attracting one kind to the nearer side of the unelectrified body and repelling the other to the farther side.

7. See page 234.

8. See Experiment 196.

9. When the tinfoil within the jar becomes charged with positive electricity from an electrophorus or other electrical machine, negative electricity is induced on the tinfoil without the jar. There the positive electricity induced, being repelled, escapes through the hand to the earth, thus leaving the outer surface charged with negative electricity. When the jar is discharged, the tinfoil without and that within the jar are brought into close proximity through a conductor known as a discharger. The electricity then leaps across the intervening space, and the electricity within and without the jar are neutralized.

10. The Leyden jar receives and retains a number of charges of electricity, and when discharged presents nearly all of them in one.

11. The student received a shock of electricity because his body acted as a discharger, the connection being made through the earth. He should have stood upon a glass plate or other insulator.

12. Lightning-rods are pointed in order that the discharge may be silent.

Experiment 207, page 254.

One hundred feet of No. 30 copper wire offers more resistance than one hundred feet of No. 16 copper wire.

One hundred feet of No. 30 copper wire offers greater resistance than fifty feet of the same. Fifty feet of No. 30 German silver wire offers more resistance than fifty feet of No. 30 copper wire.

Experiment 208.

When the plates are near together the galvanometer shows the greater strength of current.

Experiment 209.

With the copper and zinc the needle was deflected the more. If we replace the copper with carbon, it will be deflected still more.

Problems, page 259.

1. Solution given.
2. $C = \dfrac{E}{R + r} = \dfrac{8 \text{ volts}}{3 \text{ ohms}} = 2\tfrac{2}{3}$ ampères.
3. $\dfrac{15 \text{ volts}}{25 \text{ ohms}} = \dfrac{3}{5}$ ampères.
4. $R + r = \dfrac{E}{C} = \dfrac{15 \text{ volts}}{1.5 \text{ ampères}} = \dfrac{150}{15} = 10$ ohms.
5. $E = C(R + r) = 7$ ampères $\times$ 8 ohms $= 56$ volts.

Experiment 212, page 264.

The hydrogen is the electro-positive element, the oxygen the electro-negative.

Experiment 222, page 276.

When the magnets are withdrawn from the helix, the current produced is in the opposite direction to that caused by plunging in the magnets. When the south poles are plunged in, the current is in the opposite direction to that caused by plunging in the north poles. To give a current

in the same direction as that produced when the south poles are withdrawn, the north poles must be plunged in, and *vice versa.*

Experiment 223, pages 278, 279.

The currents produced in the secondary coil by putting in and taking out the primary coil agree in direction with the currents produced by putting in and taking out the corresponding poles of a bar magnet.

As the lines of force traverse iron more readily than air, the presence of the iron wire inside the primary coil renders the lines of force greater in number, and so produces a stronger current in the secondary coil.

Experiment 224, page 281.

The current, varying with the pressure on the carbon, causes the strength of the magnet to vary, and so the disk E moves.

Questions and Problems, pages 301–303.

1. See page 238. Zinc should be amalgamated to prevent its being eaten away by the acid when the wires are disconnected. Amalgamating also prevents local currents in the zinc.

2, 3. See page 240.

4. See page 241.

5. In the cell the current always flows from the zinc to the other element ; outside the cell, in the wire, it flows to the zinc from the other element.

6. The surface of the silver plate is covered with finely divided platinum.

7. The essential parts of a voltaic cell are two elements, electrically related to each other as positive and negative, and an exciting fluid.

8. After a gravity cell has worked some time, it will be observed that there are two liquids in the jar, a solution of copper sulphate, which is heavy and sinks to the bottom, and a solution of lighter zinc sulphate, which floats on the top. Hence the name.

9. See the Summary, page 299. The parts of an electro-magnet are the helix and the core.

10. The electric telegraph works upon the principle of the electro-magnet.

11. See page 246.

12. See Fig. 220 and page 248.

13. See page 250.

14. See page 251. The influence of the earth's magnetism upon one of the pair of needles counteracts the influence upon the other needle.

15. See page 250.

16. See the Summary, page 299. External resistance depends upon the length, cross-section, and material of the conductor.

17–21. See Summary, pages 299, 300.

22. See Figs. 231, 232, 233.

23. $C = \frac{E}{R + r} = \frac{7.5 \text{ volts}}{9 \text{ ohms}} = \frac{75}{90} = \frac{5}{6}$ ampères.

24. $\frac{11 \text{ volts}}{33 \text{ ohms}} = \frac{1}{3}$ ampères.

25. $C = \frac{E}{R + r}$. $\therefore C(R + r) = E$. $\therefore R + r = \frac{E}{C}$.

$$R + r = \frac{9 \text{ volts}}{1.8 \text{ ampères}} = \frac{90}{18} = 5 \text{ ohms.}$$

26. $C = \frac{E}{R + r}$. $\therefore C(R + r) = E$.

$$E = 2.2 \text{ ampères} \times 12 \text{ ohms} = 26.4 \text{ volts.}$$

27. 1.5 volts, E. M. F. of one cell, $\times$ 4, no. of cells, $=$ 6 volts.
1.5 ohms, resistance in one cell, $\times\ 4 = 6$ ohms $= r$.

$$C = \frac{E}{R + r} = \frac{6 \text{ volts}}{8 \text{ ohms} + 6 \text{ ohms}} = \frac{6}{14} = \frac{3}{7} \text{ ampères.}$$

28. 1.5 volts $=$ E. M. F. of one cell, and of four cells arranged parallel.

1.5 ohms, r of one cell, $\div$ 4, no. of cells, $=$ .375 ohms.

$$C = \frac{E}{R + r} = \frac{1.5 \text{ volts}}{8 \text{ ohms} + .375 \text{ ohms}} = \frac{1.5}{8.375} = .179 \text{ ampères.}$$

29. 1.5 volts $\times$ 2, no. of cells in series, $=$ 3 volts, E. M. F. of one pair, and of two pairs arranged parallel.

1.5 ohms, r in one cell, $\times$ 2, no. of cells in series, $\div$ 2, no. of pairs arranged parallel, $=$ 1.5 ohms.

$$C = \frac{E}{R + r} = \frac{3 \text{ volts}}{8 \text{ ohms} + 1.5 \text{ ohms}} = \frac{3}{9.5} = \frac{30}{95} = \frac{6}{19} \text{ ampères.}$$

30. 1.25 volts, E. M. F. of one cell, $\times$ 6, no. of cells in series, $= 7.5$ volts.

1.5 ohms, r of one cell, $\times\ 6 = 9$ ohms, resistance in six cells arranged in series.

$$C = \frac{E}{R + r} = \frac{7.5 \text{ volts}}{20 \text{ ohms} + 9 \text{ ohms},} = \frac{7.5}{29} = \frac{75}{290} = \frac{15}{58} = .259 \text{ ampères},$$

current strength when the cells are arranged in series.

1.25 volts, E. M. F. of one cell, and of six cells arranged parallel.

1.5 ohms, r of one cell, $\div\ 6 = .25$ ohms, r of six cells arranged parallel.

$$C = \frac{E}{R + r} = \frac{1.25 \text{ volts}}{20 \text{ ohms} + .25 \text{ ohms}} = \frac{1.25}{20.25} = \frac{125}{2025} = \frac{5}{81} = .062 \text{ am-}$$

pères, current strength when the cells are arranged parallel.

Series is in this case the better arrangement.

31. $C = \dfrac{E}{R + r} = \dfrac{2 \text{ volts}}{5 \text{ ohms } (r \text{ not given})} = \dfrac{2}{5}$ ampères.

32. $C = \dfrac{E}{R} = \dfrac{1.5 \text{ volts}}{5 \text{ ohms}} = \dfrac{15}{50} = \dfrac{3}{10}$ ampères in A.

Resistance in B : resistance in A :: cur. str. in A : cur. str. in B.

3 ohms : 5 ohms :: $\dfrac{3}{10}$ ampères : $\dfrac{5}{10}$ ampères.

See page 263 for law of divided circuit.

33. See Fig. 235, page 263. The hydrogen is given off at the negative electrode ; the oxygen, at the positive electrode.

34. See page 267.

35, 36. See Experiment 215.

37. The copper should be attached to the negative pole

38.

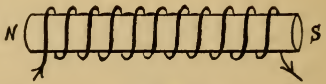

Fig. 24.

39. The current, if strong, would tend to make the needle dip.

40. The force, or pressure, with which electricity moves forward in the voltaic circuit is called electro-motive force. The quantity of elec-

tricity which in any unit of time traverses a section of a conductor determines the current strength.

41. The number of ampères, which we have called the current strength, is the same at either end of the wire. The smaller end of the wire, if small enough, will have the higher temperature.

Where, then, is the loss of electrical energy manifested which here has been transformed into heat? Question 17 brings to notice the fact that ampères alone are not a measure of electrical energy. The mechanical effectiveness of a current depends upon both current strength in ampères and the E. M. F. under which the current is moving. It is measured in *watts* or *voltampères.*

A watt is the energy of an electric current of one ampère impelled by an E. M. F. of one volt. In any current the number of watts, or voltampères, equals the product of the volts by the ampères, or $W = CE$. This product determines the amount of work that the current can do, and in doing work, such as heating the wire in the case before us, watts are expended. One horse-power = 746 watts.

Here it might be well to add that in any uniform conductor there is a constant falling off in potential, and so a decrease in E. M. F., as the distance from the source of the current increases.

Further, a unit of measure for quantity of electricity is the *ampère-hour*, which is the quantity that traverses the section of a conductor in an hour, when $C = 1$ ampère. The *coulomb* is also in use, which is the quantity of electricity that passes in one second, when $C = 1$ ampère.

42. The direction of the current can be determined by means of a magnetic needle. See Ampère's rule, page 250.

43. There are two causes for the delicacy of the galvanometer made with an astatic pair. (1) The astatic needle turns freely and without hindrance from the directive influence of the earth's magnetism. (2) The current in the wire, where it passes between the needles of the pair, tends to turn both needles in the same direction.

44, 45. See Experiment 215.

46. See page 279.

47. By making a change in the number of lines of force that pass through the space enclosed by a coil of wire a current of electricity is induced in the coil. This change may be effected by moving toward or from the coil a magnet or an electrical conductor through which a current is flowing, or by making, breaking, or altering the strength of a current in a neighboring conductor.